AD-A102 594 SCIENCE APPLICATIONS INC MONTEREY CA F/G 4/2
ATLANTIC HURRICANE STRIKE PROBABILITY PROGRAM (STRIKPA).(U)
JUL 81 J D JARRELL N00228-78-C-3337
UNCLASSIFIED SAI-1-425-02-228-01 NEPRF-CR-81-04 NL

1 OF 1
AD A
102594

END
DATE
FILMED
9-81
DTIC

NAVENVPREDRSCHFAC
CONTRACTOR REPORT
CR-81-04

ATLANTIC HURRICANE STRIKE PROBABILITY PROGRAM (STRIKPA)

Prepared By:

Jerry D. Jarrell
Science Applications, Inc.
Monterey, CA 93940

Contract No. N00228-78-C-3337

JULY [redacted]81

Prepared For:
NAVAL ENVIRONMENTAL PREDICTION RESEARCH FACILITY
MONTEREY, CALIFORNIA 93940

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NAVENVPREDRSCHFAC Contractor Report CR 81-04	2. GOVT ACCESSION NO. AD-A102 594	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Atlantic Hurricane Strike Probability Program (STRIKPA)		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER 1-425-02-228-01
7. AUTHOR(s) Jerry D. Jarrell		8. CONTRACT OR GRANT NUMBER(s) N00228-78-C-3337
9. PERFORMING ORGANIZATION NAME AND ADDRESS Science Applications, Inc. 2999 Monterey-Salinas Highway Monterey, CA 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS PE 63207N PN 7W0513 TA CC00 NEPRF WU 6.3-14
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command Department of the Navy Washington, DC 20361		12. REPORT DATE July 1981
		13. NUMBER OF PAGES 30
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Environmental Prediction Research Facility Monterey, CA 93940		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tropical cyclone
Hurricane

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A program to accept Atlantic hurricane forecasts and create estimates of hurricane strike probabilities is described. The probabilities are based on a tri-modal bivariate normal distribution of forecast errors. The relationship of the occurrence of each mode to such predictors as motion components, geographical position and maximum wind is documented. Results of independent testing are reported. It is expected that strike probabilities will be available during the 1981 hurricane season. The format of input and a description of routine and special products are provided.

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

1.0 INTRODUCTION

The Atlantic Hurricane Strike Probability (STRIKPA) model is an interim step in the development of the Atlantic Wind Probability (WINDP-ATL) model. The concepts are for the most part identical to the western Pacific and eastern Pacific models. The exceptions are the way forecast difficulty is treated and the number and listing of stations for which strike probabilities are routinely computed.

2.0 MODEL DESCRIPTION

2.1 Basis for Forecast Difficulty Estimation

The basis for forecast difficulty estimation follows Crutcher (1980)[1]. Using a clustering model (NORMIX) Crutcher identified three discrete bivariate normal populations of 24-hour forecast errors in the Atlantic Basin for the years 1970-1979. These are illustrated by 50% probability ellipses in figure 1.

Some modifications to Crutcher's work was necessary. The errors he used were adjusted for warning position error (WPE), but since this cannot be specified operationally it was necessary to replace this adjustment. An implicit assumption here is that the reintroduction of the WPE does not change the clustering. For any position on figure 1 (any 24-hour forecast error) there is a unique set of three probabilities whose sum is unity which is associated with the

---

[1] Crutcher, H.L., 1980: Tropical Storm Forecast Error and the Bivariate Normal Distribution. 13th Tec. Conference on Hurricanes and Tropical Meteorology. AMS, Miami, FL, 1-5 Dec 1980.

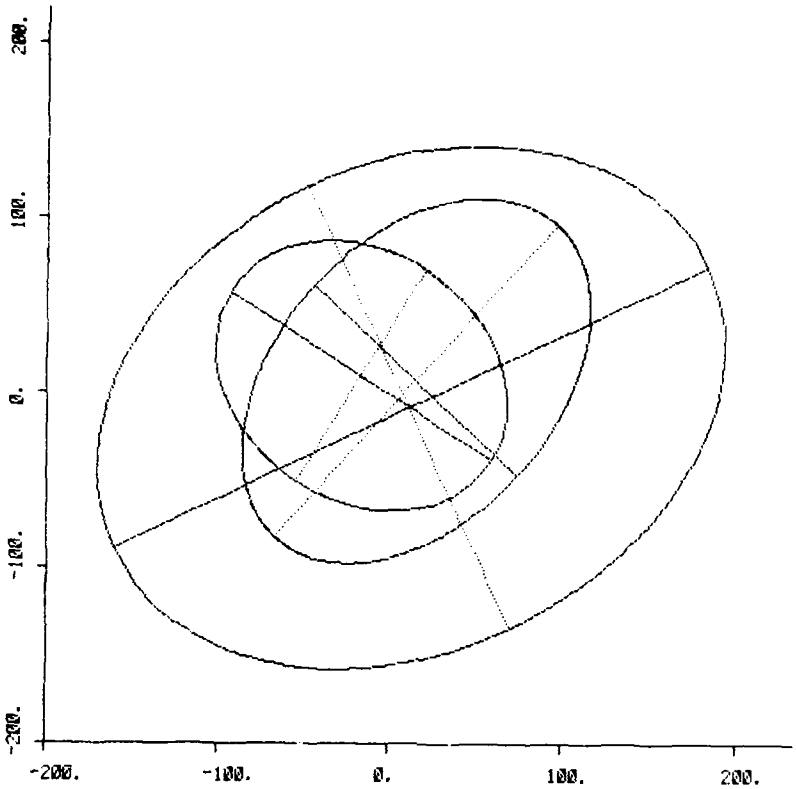

Figure 1. Fifty percent probability ellipses of 24-hour forecast errors for difficulty class ONE, TWO and THREE forecasts. The size of the ellipses increase with increasing class number. Units are n mi.

three populations. Three population probabilities were determined for each case with the WPE removed. The WPEs were then reintroduced and the population statistics were recomputed. Table 1 compares statistics for the three populations with the WPE removed (provided by Crutcher for years 1970-1979) to those with the WPE (1970-1978; 1979 was withheld for testing).

POPULATION	ONE		TWO		THREE	
	WPE	No WPE	WPE	No WPE	WPE	No WPE
W-E Mean	-16.9	-16.0	14.9	13.1	11.0	8.6
S-N Mean	9.7	5.1	6.9	1.8	-8.2	-14.3
W-E St Dev	72.3	69.6	86.0	90.0	154.7	167.4
S-N St Dev	65.4	62.6	88.8	85.3	127.1	132.2
CORR COEF (W-E error to S-N error)	-.206	-.212	.391	.452	.237	.259

Table 1. Comparison of bivariate normal parameters with and without warning position error (WPE). The 'WPE' column was based on 24-hour forecasts for years 1970-1978, while those in the 'No WPE' column, not only have been adjusted for WPE, but also include one additional year, 1979. Units are nmi.

Some of the differences in Table 1 are attributable to the withholding of 1979 from the data set, but most are clearly related to the reintroduction of the WPE. In any case the differences do not appear to be of the magnitude that would influence the clustering measurably.

CLASS	ONE			TWO			THREE		
	NA	WP	EP	NA	WP	EP	NA	WP	EP
24 h	81	99	94	99	130	97	160	148	132
48 h	200	204	176	236	251	188	325	286	254
72 h	362	324	275	394	378	297	477	407	393

Table 2. Average forecast errors (n mi) for difficulty classes ONE, TWO and THREE as defined for the northwestern Pacific (WP), northeastern Pacific (EP) and the North Atlantic (NA) ocean basins.

For comparison purposes the estimated average forecast errors for the three Atlantic hurricane forecast populations have been compared with difficulty classes ONE, TWO and THREE in the northwest and northeast Pacific ocean basins (Table 2). In the Pacific, the method of separation was quite different not only from the Atlantic, but for the two Pacific basins. Nonetheless, Class ONE in each case represents the easier forecasts and class THREE the more difficult. Class TWO appears to be less related in the different basins, resembling more class THREE in the western Pacific and Class ONE in the eastern Pacific. In the Atlantic, class TWO appears to retain a separate character.

One can see evidence of a variety of distinctions between conditions in the three ocean basins. For example, positioning, with combinations of satellite, land radar and aircraft is far superior in the Atlantic. This shows up best in the short range (Class ONE) easiest forecast. Forecast errors are in general less in the eastern Pacific for several reasons, but major among these are the rapid demise (hence non verification) of recurving cyclones and the dominance of highly persistant westward tracks. Long range (72-hour) forecasts are much better in the western Pacific

than in the Atlantic while short range forecasts are generally better in the Atlantic. These differences are no doubt related to (a) more abundant reconnaissance in the Atlantic (improves short range forecasts); (b) emphasis on long range forecasts in the military oriented western Pacific forecasts, versus the short range public warning forecast, and (c) a greater frequency of low latitude (and hence easier long range forecast) cyclones in the western Pacific.

Figure 2 shows the three populations for the Atlantic as sets of nested 50% ellipses at 0, 12, 24, 48 and 72 hours. It is apparent that although clustering was performed on 24-hour forecasts, contrast between populations is present at all time intervals.

Several methods were tried in the current work to identify conditions attendant with forecasts in each of the three groups. To set the stage for this investigation one can think of a particular forecast error as a point on figure 1. Points near the origin could likely have come from any of the three populations while points far removed are much more likely to have come from the large error population (population THREE). Thus we can never specify with certainty from which population a particular forecast came even after we can verify its error. It is even more difficult to establish before hand, into which population an error will fall.

After the fact, we can establish the relative probability that an error came from each of the populations. This is based on the probability density (height of the probability surface) at the error point (i.e., on figure 1) under each of the three bivariate normal distributions. The

Figure 2. Nested fifty percent probability ellipses for 0,12, 24,48 and 72 hours. Difficulty classes ONE, TWO and THREE are top to bottom, figures 2a, 2b and 2c, respectively. Units are in n mi.

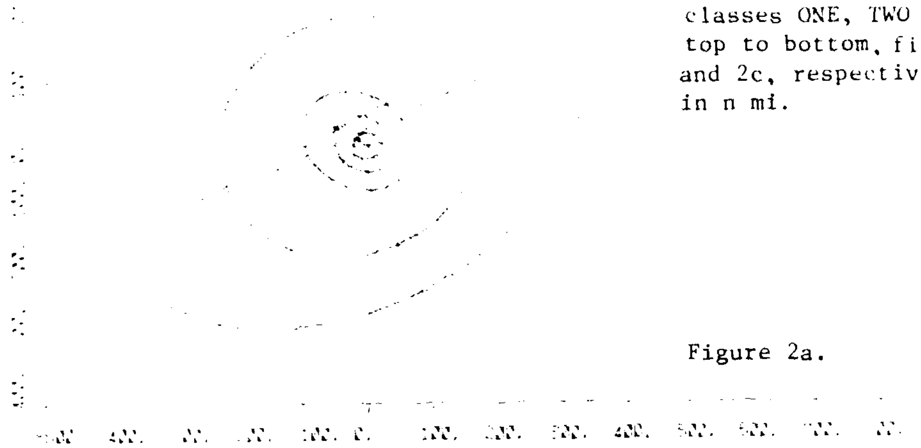

Figure 2a.

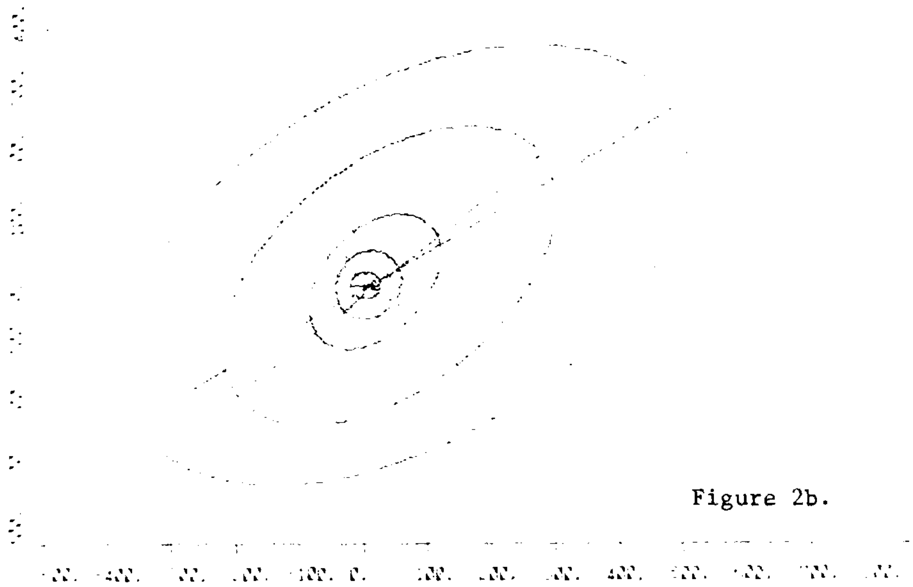

Figure 2b.

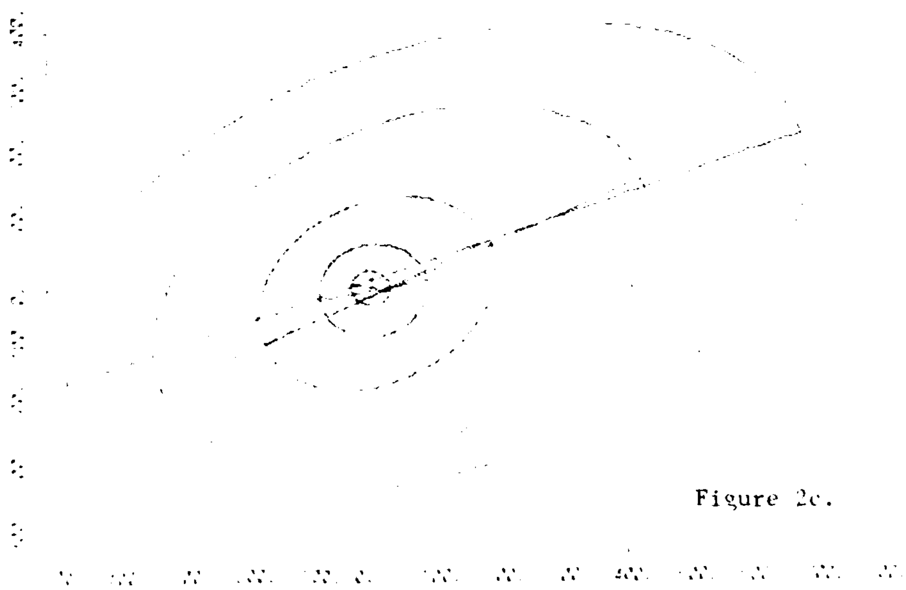

Figure 2c.

problem is first to forecast these population probabilities, or the position on figure 1. Once they are forecast, one must either select *one population* or use a combination. For probability purposes it is more reasonable to use a combination for two important reasons.

1. The relative probability of an error coming from any one population is rarely large (i.e., >60%). Thus, there is usually a sizable risk that the wrong population will be used.
2. Any predictive scheme which selects one population will be sensitive to changes in its predictors. There will be times when a small, perhaps meaningless, change in one predictor will alter the population selection and cause a large swing in the resulting strike or wind probabilities. This is undesirable since it undermines user confidence particularly if the probabilities oscillate at critical times.

2.1.1 Predicting the Population Probabilities. The most obvious method of discriminating between populations is on the basis of geography. Population ONE tends to be associated with low latitude tropical cyclones in the easterlies. Population THREE is associated with high latitude and recurving or post-recurvature cyclones. Speed of motion and direction of motion seems also to be important. Slow moving storms and westward moving storms are more often population ONE where fast moving and north or northeast tracks are predominately population THREE. Population TWO doesn't appear to be readily identified with usually recognized difficulty factors and may rather be a hybrid group which are otherwise population ONE or THREE recognized incorrectly

by the forecaster, or they may be unusual forecasts (looper stallers, etc.).

Figure 3 shows the behavior of probabilities of populations ONE, TWO and THREE averaged over small increments of latitude. Notice that the probabilities are high (> 0.5) for population ONE at low latitudes and drop off with increasing latitude. The opposite is true for population THREE. Linear correlations are high, average probability of population ONE, TWO and THREE correlated to latitude gives coefficients of -0.83, 0.03 and 0.77. Certainly the first and last are high enough so that latitude should be an excellent predictor for the average case. In individual forecasts, however, those correlation coefficients drop sharply to -0.29 and 0.27, respectively. Since the present interest is in individual cases the high composite correlation is useless.

Simply using average values on a geographic grid (i.e., 5° lat-lon Marsden squares) provides little variability in the population probabilities. Prior screening on direction speed increases the variability, but the further stratification reduces the case numbers falling within 5° squares to the extent that considerable smoothing is necessary. Such smoothing has the effect of destroying the contrast created by prior screening.

A set of typical difficulty predictors was created and matched with the population probabilities. The means, standard deviations and the correlation matrix are given in Table 3. As can be seen from Table 3, the probabilities (P_1, P_2 and P_3) are not well correlated with any of the parameters usually related to forecasting difficulty.

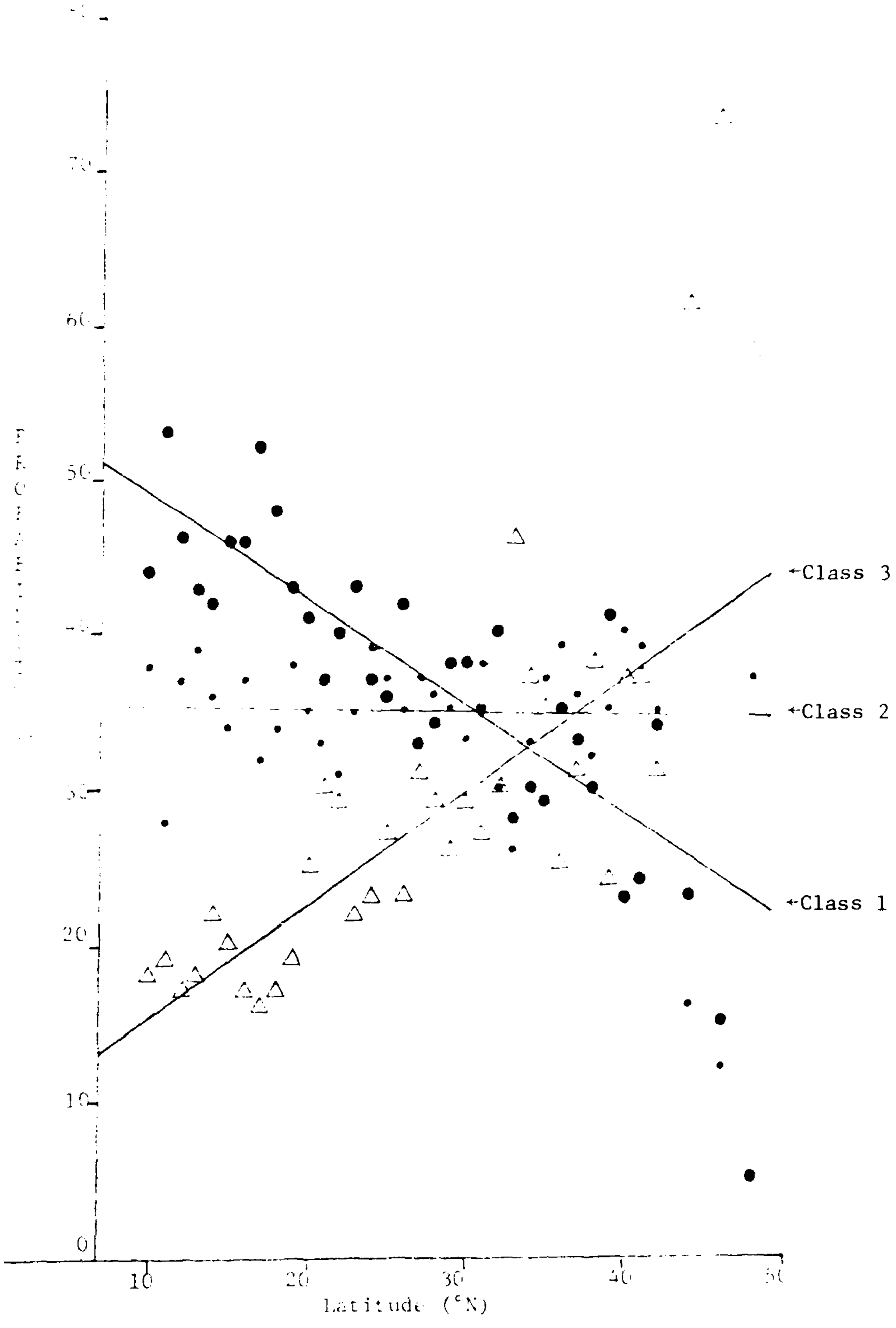

Figure 3. Scatter diagram of probabilities of a forecast being class ONE (●), TWO (•) or THREE (△) averaged over 1° latitude bands. Lines are least squares fit to the average probabilities.

However, the larger correlations (>0.14) are significant (assuming about one-fourth of the 822 cases (200) are independent). Stepwise linear regression equations were fit to the data. The equations are also given in Table 3. These equations were tested on 1979 forecasts as independent data, and the correlation between the observed and predicted probabilities was .36 for P_1 and .32 for P_3. P_2 was negatively correlated with its predicted value so it will be treated as a slack variable ($P_2=1-P_1-P_3$).

Once the probabilities are predicted, they are adjusted in two ways.

(1) Each of the probabilities is constrained to be $0 \leq P_i \leq 1$.

(2) As mentioned above probability P_2 is set equal to $1 - P_1 - P_3$.

2.1.2 Using the Predicted Population Probabilities in the Model. The strike probability code generates three runs; each run using the bivariate parameters from a different population. The final probabilities are a sum weighted by the predicted population probabilities. Symbolically this is

$$P(\varepsilon) = \sum_{i=1}^{3} P(\varepsilon|k=i)\ P(k=i) \quad ,$$

where $P(\varepsilon)$ is the probability of some event ε, $P(\varepsilon|k=i)$ is the probability of event ε given that we have a population i forecast, and $P(k=i)$ is the probability that the current forecast is indeed from population i.

	P_1	P_2	P_3	LAT	LON	V_m	U	V
Mean	0.375	0.351	0.274	26.9	66.0	[illegible]	[illegible]	[illegible]
Std. Dev.	0.195	0.129	0.211	8.1	10.2	[illegible]	[illegible]	[illegible]
Units	None	None	None	deg	deg	[illegible]	[illegible]	[illegible]
Corr With								
P_1	1.0							
P_2	-.432	1.0						
P_3	-.800	-.205	1.0					
LAT	-.289	-.011	.274	1.0				
LON	.189	.059	-.211	-.331	1.0			
V_m	-.009	-.009	.014	.246	-.069	1.0		
U	-.334	-.010	.316	.715	-.261	.149	1.[illegible]	
V	-.148	-.089	.192	.266	-.049	.060	[illegible]	1.[illegible]

REGRESSION EQUATIONS

$$P1 = 0.3176 - .0020LAT + .0012LON + .0006Vm - .0049U - .0018V$$

$$P2 = 0.3283 + .0005LON \quad .0023U + .0005V$$

(This equation was not used. See section 2.1.1)

$$P3 = 0.3628 + .0004LAT - .0017LON + .0003Vm + .0200U - .0064V$$

Table 3. Statistics relating class probabilities P_1, P_2 and P_3 to several predictors. Regression equations relating the probabilities to the predictors are shown across the bottom. This is based on forecasts from years 1970-78.

3.0 OPERATIONAL PRODUCTS

The strike probability product will be available under operational evaluation during the 1981 hurricane season for the North Atlantic.

<u>Product</u> Tropical cyclone strike probabilities for preselected points. This can be disseminated automatically to a distribution list by Fleet Numerical Oceanography Center (FNOC) via AUTODIN initially and possibly later via the Automated Weather Network (AWN). Included in this product will be a table of forecast confidence estimates for the Naval Eastern Oceanography Center (NEOC) Norfolk, VA.

This product could be generated routinely by FNOC upon receipt of the NEOC Norfolk retransmission of NHC Miami's tropical warning every six hours. The message would give the probabilities of a particular tropical cyclone being within 75 n mi (left) or 50 n mi (right), relative to forecast track, of twelve preselected points of Navy interest and seventeen points of Air Force interest. Although subject to change the points currently listed within the program are:

<u>Navy Points</u>	<u>Air Force Points</u>
Roosevelt Roads, PR	Howard AFB, Panama
Guantanamo, Cuba	MacDill AFB, FL
Key West, FL	Tyndall AFB, FL
Pensacola, FL	Eglin AFB, FL
New Orleans, LA	Keesler AFB, MS
Corpus Christi, TX	Ellington AFB, TX
Mayport, FL	Bergstrom AFB, TX
Charleston, SC	San Antonio Basin, TX
Morehead City, NC	Homestead AFB, FL
Norfolk, VA	Patrick AFB, FL
New London, CT	Hunter AAF, GA
Bermuda, BWI	Myrtle Beach, SC
	Andrews AFB, MD
	Dover AFB, DE
	Atlantic City, NJ
	McGuire AFB, NJ
	Pease AFB, NH

The strike probabilities, computed upon receipt of each 6-hourly warning and given at 12-hour intervals after warning time, are presented in two forms. The first is the instantaneous probability, valid at a single instant of time only. The second is a time integrated probability -- the probability that a strike will occur at some time between the effective time of the warning and multiples of 12 hours thereafter. Similarly probabilities of 30 and 50 kt winds are expected to be added to this message at a later date.

Additionally the program could be run upon special request although the implementing software is not now in place. The user would make his request to FNOC via AUTODIN. He would include information sufficient to identify the tropical cyclone, the point of concern (latitude/longitude), and the radii about that point describing the area considered to constitute a strike. The output would be in the same form as the above product (i.e., instantaneous and time integrated strike probabilities at 12-hour intervals after warning time).

An example for hurricane David at 0400 GMT 3 and 4 Sep 1979 follows to illustrate the input and output. At 0400 GMT 3 Sep David was about 80 n mi ESE of Miami with 90 kt maximum winds. He was expected to skirt the length of the Florida east coast and thereafter go inland in the Carolinas on a recurving track up the Atlantic seaboard. Since David was still on a northwest track, either a continuation of that track into the Gulf of Mexico or the forecast recurvature track was possible; thus stations along the east coast as well as those in the Gulf of Mexico were under some threat.

Two Atlantic Strike Probability Programs (STRIKPA) runs for David are discussed below.

Run 1 is a standard FNOC originated run at 04/0400 GMT.

Run 2 is in response to a hypothetical user at 03/0400 GMT specifying an area within 50 n mi of Cape Kennedy (28.4N, 80.6W). His request would have gone to FNOC via AUTODIN message in APR format (Table 4 gives a probable APR format when and if individual user runs are provided). Required input would be at least one Area of Concern (lat/long) and radii to the left and right of that point (relative to forecast motion).

Tables 5 and 6 illustrate the output from Runs 1 and 2, respectively. These tables also contain some descriptive information. It should be noted that a users manual will be distributed to operational users of STRIKPA prior to the dissemination of this product.

```
BT
UNCLAS//N03160
TROPICAL CYCLONE STRIKE PROBABILITY REQUEST, ATLANTIC
Q92X0001
/APR,AP(STRIKPA), (other entries on this line as required)
/STM,NM(DAVID),NR(NA04),DH(7909030400)/
/AOC,LA(284N),L)(806W),RL(50),RR(50)/
.
.
.  (as many AOC lines as needed)
.
.
.
/AAD,
etc. (as needed)
/PARA,
/ERK/  (required end)
BT
```

/STM:	Storm line
NM:	Name of cyclone
NR:	Cyclone number, Ocean Basin NA=North Atlantic
DH:	Effective Dat/time of warning. DH(7909030400) = 030400Z Sep 1979 (Day 03 hour 0400 GMT)
/AOC:	Are of concern line
LA:	Latitude of point of concern. LA(284N)=28.4° north
LO:	Longitude of point of concern. LO9806W=80.6° west.
RL:	Radius of area of concern to left of storm's track
RR:	Radius of area of concern to right of storm's track. Usually RL is greater than RR. Default values of 75/50 n mi will be used if both RL and RR are zero or blank.

Note: One input record will be rewritten for each /AOC (including storm information). Request message in accordance with FLENUMWEACEN, 1977: ASWOCAS Request Procedures Manual, Vol. 2.

Table 4. Sample Automated Product Request (APR) System Message. This information is tentative since software to accept this request is not currently in place.

Run 1 Output (Product 1)

STRIKE PROBABILITY FORECASTS

DAVID 040400Z

ROOSEROADS	THREAT NIL*						
GUANTANAMO	THREAT NIL						
KEY WEST	THREAT NIL						
PENSACOLA	00ININ*	12ININ	24ININ	36ININ	48IN01	60IN01	72IN02
NEWORLEANS	00ININ	12ININ	24ININ	36ININ	48ININ	60ININ	72IN01
CORPUR CHR	THREAT NIL						
MAYPORT	00ININ	124250	240451	360251	480151	600151	72IN51
CHARLESTON	00ININ	12ININ	242333	360833	480333	600233	720133
MOREHD CTY	00ININ	12ININ	240304	360714	480417	600218	720118
NORFOLK	00ININ	12ININ	24ININ	360306	480411	600313	720214
NEW LONDON	00ININ	12ININ	24ININ	36ININ	48IN01	600104	720207
BERMUDA	00ININ	12ININ	24ININ	36ININ	48ININ	60ININ	72IN01

FOR NEOC NORVA: FORECAST CONFIDENCE TABLE

TIME	PROB	DIST	PROB	DIST	PROB
12HR	50	50	26	75	24
24HR	48	100	25	150	27
48HR	33	200	25	300	42
72HR	28	300	24	450	48

DIST are radii of circles about forecast positions. PROB are probabilities that verifying position will be within inner circle, between circles or outside outer circle respectively. For example, probability that 24-hr forecast error is less than 100 nm is 48%; between 100-150 nm is 25%; and greater than 150 nm is 27%.

PROBABILITIES BASED ON FOLLOWING FORECAST

002810803080 123000805080 243250797085 483500770070 723800760065

FORECASTS: Time 12 hr Latitude 30.0N Longitude 80.5W Max Wind 80 Kts

LAT/LONG of preselected points are stored within program. Strike is predefined to occur if tropical cyclone passes within 75 nm radius (left) or 50 nm radius (right) of track of tropical cyclone.

*THREAT NIL means all probabilities for this station were <0.5%. IN means insignificant (<0.5%).

Table 5. Output from Run (1).

Run 2 Output (Product 2)

STRIKE PROBABILITIES FOR TROPICAL CYCLONE DAVID

FROM 030400Z BASED ON FOLLOWING FORECAST

002430776090 122610803100 242800810065 483200815035 723600790025

STRIKE IS BEING WITHIN 50NM RIGHT AND 50NM LEFT OF 28.4N 80.6W

STRIKE PROBS** 00ININ 120101 241727 360428 480128 600128 72IN28

24 17 27

24	Time 24 hours after synoptic time 030000GMT
17	The probability of a "strike" at 040000Z (030000 + 24 hr) is 17%
27	The probability of a "strike" between 030000Z and 040000Z (24 hour period) is 27%

ABBREVIATIONS:

Number 01-99; strike probability in %

IN = insignificant; p<0.5% Prevents representation of 0% and 100% which occur only as an approximation.

The input forecast data is error checked only in that the tropical cyclone forecast motion is computed between forecast points. If vector motion deviates substantially from the climatological mean, the following warning message will appear in all products:

UNUSUAL MOTION -- PLEASE RECHECK WARNING DATA

**Note that although the forecast warning time is 040400Z, the 00ININ reflects an extrapolation of minus four hours to 040000Z, whereby the program is initialized. All subsequent time intervals are from 040000Z initialization. This minus four hour extrapolation is an internal program adjustment. The 00 position in the "PROBABILITIES BASED ON FOLLOWING FORECAST" section of the output message is also an extrapolated position.

Table 6. Output from Run (2).

4.0 TESTING

The 1979 Atlantic tropical cyclone forecasts were withheld from the developmental data as a test set. This set consisted of 245 nowcasts and 214 12-hour forecasts, 195 24-hour forecasts, 112 48-hour forecasts and 99 72-hour forecasts which could be verified.

The testing consisted of running strike probability forecasts off Atlantic hurricane (and lesser tropical cyclone) forecasts for 12 Navy points of current interest and an additional 24 points scattered throughout the open water areas of the North Atlantic and Gulf of Mexico. The Navy points are listed in section 3.0.

Tables 7 and 8 compare the expected to observed number of "strikes". Predictions were grouped into cells of increasing width, <½%, ½ to 1½%, 1½ to 3½%, etc. and strikes observed based on best track. Time integrated probabilities over t hours were verified only if a continuous record of verifying positions was available for t hours. This prevents an obvious bias by excluding of necessity those that die before they reach a station but including those which strike within the first few hours. This is progressively less important in shorter range forecasts.

It is difficult to assess the significance of such information, but verification is obviously necessary. To illustrate the problem in establishing the significance of differences in expected vs observed, let's assume we want to use a test on whether the two are different. One such test assumes the number of successes (expected) in N Bernoulli trials is given by PxN where P is the probability of a single success. Our P is the forecast strike probability.

	24 Hour			48 Hour			72 Hour		
A < P < B	EXP	OBS	CASES	EXP	OBS	CASES	EXP	OBS	CASES
0 - ½%	0	0	6731	0	0	3627	0	0	2974
½% - 1½%	0	0	75	2	2	186	4	3	429
1½% - 3½%	2	2	56	5	6	147	3	7*	161
3½% - 7½%	4	1	59	3	5	72	0	0	0
7½% - 15½%	7	5	60	0	0	0	0	0	0
15½% - 31½%	13	10	39	0	0	0	0	0	0
31½% - 63½%	0	0	0	0	0	0	0	0	0
63½% - 100 %	0	0	0	0	0	0	0	0	0
	21	18	7020	10	15	4032	7	10	3564

Table 7. Comparison of expected to observed number of strikes based on an independent sample of 1979 Atlantic tropical cyclone forecasts. Strike probabilities were computed on 245 warnings and for 12 stations plus 24 other points in the open Atlantic. These are for instantaneous probabilities and a strike was considered to have occurred if the nowcast probability exceeded 50%.

*Differences are significant (α=0.05)

	24 Hour			48 Hour			72 Hour		
A < P < B	EXP	OBS	CASES	EXP	OBS	CASES	EXP	OBS	CASES
0 - ½%	0	0	6554	0	0	3385	0	0	2542
½% - 1½%	0	1	53	2	0	170	3	1	226
1½% - 3½%	0	0	45	3	0	122	5	0*	213
3½% - 7½%	3	2	59	5	0*	93	12	1*	240
7½% - 15½%	5	5	50	14	15	124	23	29	210
15½% - 31½%	14	10	63	18	25	88	19	32*	91
31½% - 63½%	26	23	60	17	12	37	13	10	31
63½% - 100 %	23	21	28	10	10	13	9	8	11
	71	62	6912	69	62	4032	84	81	3564

Table 8. Same as Table 7 but time integrated probabilities are given.

*Indicates differences are significant (α=0.05)

We can use a binomial distribution to see if our observed "strikes" is close enough to the expected. In Table 7, the worst comparison was 3 expected vs 7 observed with 161 cases (72-hour instantaneous). The number three was arrived at by noting the average strike probability in that cell ($1\frac{1}{2}$ to $3\frac{1}{2}$%) was 2%, and 2% of 161 is rounded to 3. The standard deviation on the 2% is 1.1% using 161 independent cases. Five percent of the time we expect the "observed" to fall more than 1.96 standard deviations away from the mean or outside the interval 0 to 4.2%. Since we observed 4.35% (7/161), we might be alarmed, this represents 2.14 standard deviations away from 2.00 which is significant. The problem of interdependence can be seen by noting there are only 195 24-hour forecasts, yet there are (from Table 7) 7020 24-hour strike probability forecasts. These are obviously interrelated. To correct for this we usually assume one-fourth of the cases are independent. When we do that none of the differences in Tables 7 and 8 are significantly different. With or without this assumption, the agreement between observed and expected is excellent.

To provide more insight into the behavior of the STRIKP's as a hurricane threatens, a summary of the STRIKP's for the 72 hours prior to the six 1979 strikes on the Navy test points is provided as Tables 9 and 10. Those probabilities which were counted as having verified as a strike are underlined. Some which verified were not counted because they were not observable during the entire verification period. Notice that some of the small (under 2%) probabilities actually verified. With Frederick, even a 12-hour 1% forecast resulted in a strike on Guantanamo. That was a case of an ill-defined depression whose track was, and still is, in doubt.

HURRICANE BOB .. NEW ORLEANS 11 JULY 1979 1600GMT

BOB	101600Z	NEWORLEANS	00ININ	12ININ	241825	360727	480228
BOB	102200Z	NEWORLEANS	00ININ	120202	242039	360439	480139
BOB	110400Z	NEWORLEANS	00ININ	121921	241647	360347	480147
BOB	111000Z	NEWORLEANS	00ININ	124378	240178		
BOB	111600Z	NEWORLEANS	008484	120192	24IN92		

TROPICAL STORM CLAUDETTE .. ROOSEVELT ROADS, P.R. 18 JULY 1979 1000GMT

CLAUDETTE	161600Z	ROOSEROADS	THREAT	NIL					
CLAUDETTE	162200Z	ROOSEROADS	THREAT	NIL					
CLAUDETTE	170400Z	ROOSEROADS	00ININ	12ININ	240406				
CLAUDETTE	171000Z	ROOSEROADS	00ININ	12ININ	241827				
CLAUDETTE	171600Z	ROOSEROADS	00ININ	122931	240457	36IN57	48IN57	60IN57	72IN57
CLAUDETTE	172200Z	ROOSEROADS	00ININ	122859	24IN61	36IN61	48IN61	60IN61	72IN61
CLAUDETTE	180400Z	ROOSEROADS	000707	120283	24IN83	36IN83	48IN83	60IN83	72IN83
CLAUDETTE	181000Z	ROOSEROADS	006767	12IN68	24IN68	36IN68	48IN68	60IN68	72IN68

HURRICANE DAVID .. MAYPORT, FLORIDA 4 SEPT 1979 1600GMT

DAVID	011600Z	MAYPORT	00ININ	12ININ	24ININ	36ININ	480204	600206	720211
DAVID	012200Z	MAYPORT	00ININ	12ININ	24ININ	360101	480307	600310	720312
DAVID	020400Z	MAYPORT	00ININ	12ININ	24ININ	360101	480308	600311	720311
DAVID	021000Z	MAYPORT	00ININ	12ININ	24ININ	360204	480410	600312	720314
DAVID	021600Z	MAYPORT	00ININ	12ININ	24ININ	360408	480413	600414	720415
DAVID	022200Z	MAYPORT	00ININ	12ININ	240304	360917	480318	600120	720122
DAVID	030400Z	MAYPORT	00ININ	12ININ	240609	361020	480421	600222	720122
DAVID	031000Z	MAYPORT	00ININ	12ININ	240711	360819	480220		
DAVID	031600Z	MAYPORT	00ININ	120303	242235	360536	480236	600136	720136
DAVID	032200Z	MAYPORT	00ININ	122934	242247	360548	480248	600148	720148
DAVID	040400Z	MAYPORT	00ININ	124250	240451	360251	480151	600151	72IN51
DAVID	041000Z	MAYPORT	000404	123270	240370	360170	480170	60IN70	72IN70
DAVID	041600Z	MAYPORT	008797	120297	24IN97	36IN97	48IN97	60IN97	72IN97

Table 9 . Summary of strike probabilities prior to the closest point of approach (CPA) of Hurricane Bob to New Orleans, Tropical Storm Claudette to Roosevelt Roads, P.R. and Hurricane David to Mayport, Florida. Where forecasts were available strike probability estimates were computed 72 hours prior to CPA. Underlined probabilities verified in a "strike".

HURRICANE FREDERICK .. ROOSEVELT ROADS P.R. 4 SEPT 1979 [illegible] GMT

FREDERICK	011000Z	ROOSEROADS	00ININ	12ININ	24ININ	36ININ	480101	[illegible]	[illegible]
FREDERICK	011600Z	ROOSEROADS	00ININ	12ININ	24ININ	36IN01	[illegible]	600011	[illegible]
FREDERICK	012200Z	ROOSEROADS	00ININ	12ININ	24ININ	360102	480404	600212	[illegible]
FREDERICK	020400Z	ROOSEROADS	00ININ	12ININ	24ININ	360407	480512	600214	[illegible]
FREDERICK	021000Z	ROOSEROADS	00ININ	12ININ	24IN01	360612	480415	[illegible]	[illegible]
FREDERICK	021600Z	ROOSEROADS	00ININ	12ININ	240206	360616	[illegible]	[illegible]	[illegible]
FREDERICK	022200Z	ROOSEROADS	00ININ	12ININ	241018	360221	480121	60IN21	[illegible]
FREDERICK	030400Z	ROOSEROADS	00ININ	12ININ	241018	360420	[illegible]	[illegible]	[illegible]
FREDERICK	031000Z	ROOSEROADS	00ININ	120101	241726	[illegible]	[illegible]	[illegible]	[illegible]
FREDERICK	031600Z	ROOSEROADS	00ININ	121012	241954	360425	[illegible]	[illegible]	[illegible]
FREDERICK	032200Z	ROOSEROADS	00ININ	123547	241148	360548	480142	[illegible]	[illegible]
FREDERICK	040400Z	ROOSEROADS	00ININ	122083	24IN83	36IN83	[illegible]	[illegible]	[illegible]
FREDERICK	041000Z	ROOSEROADS	005555	122080	240280	36IN80	48IN80	[illegible]	[illegible]
FREDERICK	041600Z	ROOSEROADS	009898	120398	24IN98	36IN98	[illegible]	[illegible]	[illegible]

HURRICANE FREDERICK .. GUANTANAMO CUBA 7 SEPTEMBER 1979 [illegible] GMT

FREDERICK	041000Z	GUANTANAMO	00ININ	12ININ	24ININ	[illegible]	[illegible]	[illegible]	[illegible]
FREDERICK	041600Z	GUANTANAMO	00ININ	12ININ	24ININ	360407	480412	600214	[illegible]
FREDERICK	042200Z	GUANTANAMO	00ININ	12ININ	240203	360713	[illegible]	[illegible]	[illegible]
FREDERICK	050400Z	GUANTANAMO	00ININ	12ININ	24IN01	360408	480412	600214	[illegible]
FREDERICK	051000Z	GUANTANAMO	00ININ	12ININ	240206	360511	480214	600215	[illegible]
FREDERICK	051600Z	GUANTANAMO	00ININ	12ININ	240101	360408	480211	[illegible]	[illegible]
FREDERICK	052200Z	GUANTANAMO	00ININ	12ININ	240507	360817	480418	600220	[illegible]
FREDERICK	060400Z	GUANTANAMO	00ININ	12ININ	240811	360919	480220	600221	[illegible]
FREDERICK	061000Z	GUANTANAMO	00ININ	12ININ	240304	360511	480214	600215	[illegible]
FREDERICK	061600Z	GUANTANAMO	00ININ	12IN01	240611	360515	480216	600117	[illegible]
FREDERICK	062200Z	GUANTANAMO	00ININ	120101	240610	360414	480215	600116	[illegible]
FREDERICK	070400Z	GUANTANAMO	00ININ	123946	241646				
FREDERICK	071000Z	GUANTANAMO	005454	120369	240169				

HURRICANE FREDERICK .. PENSACOLA FLORIDA 13 SEPT 1979 0400GMT

FREDERICK	100400Z	PENSACOLA	00ININ	12ININ	24ININ	36ININ	480101	600104	[illegible]
FREDERICK	101000Z	PENSACOLA	00ININ	12ININ	24ININ	36ININ	480103	600207	[illegible]
FREDERICK	101600Z	PENSACOLA	00ININ	12ININ	24ININ	36IN01	480205	600206	[illegible]
FREDERICK	102200Z	PENSACOLA	00ININ	12ININ	24ININ	360101	480206	600208	720211
FREDERICK	110400Z	PENSACOLA	00ININ	12ININ	24ININ	360102	480308	600210	[illegible]
FREDERICK	111000Z	PENSACOLA	00ININ	12ININ	24ININ	360407	480412	600214	[illegible]
FREDERICK	111600Z	PENSACOLA	00ININ	12ININ	24IN01	360509	480413	600215	[illegible]
FREDERICK	112200Z	PENSACOLA	00ININ	12ININ	240102	360612	480415	600216	[illegible]
FREDERICK	120400Z	PENSACOLA	00ININ	12ININ	241622	360925	480226	600126	[illegible]
FREDERICK	121000Z	PENSACOLA	00ININ	121416	241545	360345	480145	600145	72IN45
FREDERICK	121600Z	PENSACOLA	00ININ	122935	241446	360346	480146	60IN46	72IN46
FREDERICK	122200Z	PENSACOLA	00ININ	124958	240758	360158	48IN58	60IN58	[illegible]
FREDERICK	130400Z	PENSACOLA	006262	121083	24IN83	36IN83	48IN83	60IN83	[illegible]

Table [illegible]. Same as Table [illegible], but for Hurricane Frederick during his approach to Roosevelt Roads, P.R., Guantanamo, Cuba and Pensacola, Florida.

5.0 SUMMARY

The strike probability concepts have been thoroughly tested in operational use and with independent testing in the western Pacific. The extensions of those concepts to the Atlantic are based on sound statistical principles. The Atlantic model independent test results show excellent agreement between the observed and the expected. Barring a dramatic shift in forecast accuracy, these tests and Pacific operational experience with most of the important model aspects, suggest the model will perform reliably.

DISTRIBUTION: CR 81-04

COMMANDER IN CHIEF
U.S. ATLANTIC FLEET
NORFOLK, VA 23511

U.S. ATLANTIC (N009/04E)
ATTN: NSAP SCIENCE ADVISOR
NORFOLK, VA 23511

COMMANDER IN CHIEF
U.S. PACIFIC FLEET
PEARL HARBOR, HI 96860

COMMANDER
SECOND FLEET
FPO NEW YORK 09501

COMSECOND FLT
ACOS TACTICAL DEV. & EVAL.
ATTN: NSAP SCIENCE ADVISOR
BOX 100
CINCLANTFLT COMPOUND
NORFOLK, VA 23511

COMMANDER
U.S. NAVAL FORCES, AZORES
APO NEW YORK 09406

COMMANDER
U.S. NAVAL FORCES, CARIBBEAN
FPO MIAMI 34051

COMMANDER NAVAL AIR FORCE
U.S. ATLANTIC FLEET
NORFOLK, VA 23511

COMMANDER NAVAL AIR FORCE
U.S. ATLANTIC FLEET (30F)
ATTN: NSAP SCIENCE ADVISOR
NORFOLK, VA 23511

COMMANDER NAVAL SURFACE FORCE
U.S. ATLANTIC FLEET
NORFOLK, VA 23511

COMMANDER
MINE WARFARE COMMAND
ATTN: NSAP SCIENCE ADVISOR
CODE 006
CHARLESTON, SC 29408

COMSUBFORCE
U.S. ATLANTIC FLEET
ATTN: NSAP SCIENCE ADVISOR
NORFOLK, VA 23511

COMMANDER
AMPHIBIOUS GROUP 2
ATTN: METEOROLOGICAL OFFICER
FPO NEW YORK 09501

COMMANDER OPERATIONAL TEST
AND EVALUATION FORCE
NAVAL BASE
NORFOLK, VA 23511

COMMANDER
OPTEVFOR
ATTN: NSAP SCIENCE ADVISOR
NORFOLK, VA 23511

OFFICER IN CHARGE
NEW LONDON TEST & EVALUATION
FORCE DET.
NEW LONDON LABORATORY
NEW LONDON, CT 06320

COMMANDER
SURFACE WARFARE DEV. GRP.
NAVAL AMPHIBIOUS BASE,
LITTLE CREEK
NORFOLK, VA 23521

COMMANDING OFFICER
USS AMERICA (CV-66)
ATTN: MET. OFFICER
FPO NEW YORK 09531

COMMANDING OFFICER
USS FORRESTAL (CV-59)
ATTN: MET. OFFICER
FPO MIAMI 34080

COMMANDING OFFICER
USS INDEPENDENCE (CV-62)
ATTN: MET. OFFICER
FPO NEW YORK 09537

COMMANDING OFFICER
USS JOHN F. KENNEDY (CV-67)
ATTN: MET. OFFICER
FPO NEW YORK 09538

COMMANDING OFFICER
USS NIMITZ (CVN-68)
ATTN: MET. OFFICER
FPO NEW YORK 09542

COMMANDING OFFICER
USS EISENHOWER (CVN-69)
ATTN: MET. OFFICER
FPO NEW YORK 09532

COMMANDING OFFICER
USS SARATOGA (CV-60)
ATTN: MET. OFFICER
FPO NEW YORK 09587

COMMANDING OFFICER
USS MOUNT WHITNEY (LCC-20)
ATTN: MET. OFFICER
FPO NEW YORK 09517

COMMANDING OFFICER
USS GUADALCANAL (LPH-7)
ATTN: MET. OFFICER
FPO NEW YORK 09562

COMMANDING OFFICER
USS GUAM (LPH-9)
ATTN: MET. OFFICER
FPO NEW YORK 09563

COMMANDING OFFICER
USS INCHON (LPH-12)
ATTN: MET. OFFICER
FPO NEW YORK 09529

COMMANDING OFFICER
USS IWO JIMA (LPH-2)
ATTN: MET. OFFICER
FPO NEW YORK 09561

COMMANDING OFFICER
USS NASSAU (LHA-4)
ATTN: MET OFFICER
FPO NEW YORK 09557

COMMANDING OFFICER
USS SAIPAN (LHA-2)
ATTN: MET. OFFICER
FPO NEW YORK 09549

COMMANDING OFFICER
USS PUGET SOUND (AD-38)
ATTN: MET. OFFICER
FPO NEW YORK 09544

COMMANDING OFFICER
USS LASALLE (AGF-3)
ATTN: MET. OFFICER
FPO NEW YORK 09577

COMMANDING OFFICER
USS LEXINGTON (AVT-16)
FPO MIAMI 34088

COMMANDING GENERAL
FLEET MARINE FORCE, ATLANTIC
ATTN: NSAP SCIENCE ADVISOR
NORFOLK, VA 23511

COMMANDING GENERAL
2ND MARINE AIRCRAFT WING
MARINE CORPS AIR STATION
CHERRY POINT, NC 28533

COMMANDER IN CHIEF ATLANTIC
NAVAL BASE
NORFOLK, VA 23511

SPECIAL ASSISTANT TO THE
ASSISTANT SECNAV (R&D)
RM 4E741, THE PENTAGON
WASHINGTON, DC 20350

CHIEF OF NAVAL RESEARCH
LIBRARY SERVICES, CODE 734
RM 633, BALLSTON TOWER #1
800 QUINCY STREET
ARLINGTON, VA 22217

CHIEF OF NAVAL OPERATIONS
U.S. NAVAL OBSERVATORY
OP-952
WASHINGTON, DC 20390

CHIEF OF NAVAL OPERATIONS
OP-622C
NAVY DEPARTMENT
WASHINGTON, DC 20350

CHIEF OF NAVAL OPERATIONS
ATTN: DR. R. W. JAMES, OP-952D1
U.S. NAVAL OBSERVATORY
34TH & MASS. AVE. NW
WASHINGTON, DC 20390

CHIEF OF NAVAL MATERIAL
(MAT-034)
NAVY DEPT.
WASHINGTON, DC 22332

WEATHER ELEMENT
NATIONAL MILITARY COMMAND CENTER
THE PENTAGON - RM 2D921H
WASHINGTON, DC 20301

DEPUTY DIRECTOR FOR OPERATIONS
(ENVIRONMENTAL SERVICES)
OJCS, RM 1B679, THE PENTAGON
WASHINGTON, DC 20301

DET. 2, HQ, AWS
THE PENTAGON
WASHINGTON, DC 20330

NAVAL DEPUTY TO THE ADMINISTRATOR
NOAA, RM 200, PAGE BLDG. #1
3300 WHITEHAVEN ST. NW
WASHINGTON, DC 20235

OFFICER IN CHARGE
NAVOCEANCOMDET
FEDERAL BLDG.
ASHEVILLE, NC 28801

CPOIC
NAVOCEANCOMDET, CHASE FIELD
BEEVILLE, TX 78103

OFFICER IN CHARGE
NAVOCEANCOMDET
U.S. NAVAL AIR STATION
FPO NEW YORK 09560

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL AIR STATION
BRUNSWICK, ME 04011

OFFICER IN CHARGE
NAVOCEANCOMDET
CARSWELL AFB, TX 76127

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL AIR STATION
CECIL FIELD, FL 32215

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL STATION
CHARLESTON, SC 29408

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL AIR STATION
CORPUS CHRISTI, TX 78419

CPOIC
NAVOCEANCOMDET
NAVAL AIR STATION
DALLAS, TX 75211

OFFICER IN CHARGE
U.S. NAVOCEANCOMDET
BOX 16
FPO NEW YORK 09593

OFFICER IN CHARGE
NAVOCEANCOMDET
NAS, BOX 9048
KEY WEST, FL 33040

CPOIC
NAVOCEANCOMDET
NAVAL AIR STATION
KINGSVILLE, TX 78363

PETTY OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL AIR ENGINEERING CENTER
LAKEHURST, NJ 08733

CPOIC
NAVOCEANCOMDET
NAVAL AIR STATION
MAYPORT, FL 32228

OFFICER IN CHARGE
NAVOCEANCOMDET
NAS, MEMPHIS
MILLINGTON, TN 38054

OFFICER IN CHARGE
NAVOCEANCOMDET
NAS, WHITING FIELD
MILTON, FL 32570

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL AIR STATION
MERIDIAN, MS 39301

CPOIC
NAVOCEANCOMDET
NAVAL AIR STATION
NEW ORLEANS, LA 70146

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL AIR STATION
PATUXENT RIVER, MD 20670

OFFICER IN CHARGE
NAVOCEANCOMDET
U.S. NAVAL STATION
FPO MIAMI 34051

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL AIR STATION
SOUTH WEYMOUTH, MA 02190

OFFICER IN CHARGE
NAVOCEANCOMDET
NAS, OCEANA
VIRGINIA BEACH, VA 23460

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL AIR STATION
WILLOW GROVE, PA 19090

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL AIR STATION
PENSACOLA, FL 32508

OFFICER IN CHARGE
NAVOCEANCOMDET
MONTEREY, CA 93940

COMMANDING OFFICER
OFFICE OF NAVAL RESEARCH
EASTERN/CENTRAL REGIONAL OFFICE
BLDG. 114, SECT. D
666 SUMMER ST.
BOSTON, MA 02210

COMMANDING OFFICER
NORDA, CODE 101
NSTL STATION
BAY ST. LOUIS, MS 39529

COMMANDING OFFICER
FLEET INTELLIGENCE CENTER
EUROPE & ATLANTIC
NORFOLK, VA 23511

COMMANDER
NAVOCEANCOM
NSTL STATION
BAY ST. LOUIS, MS 39529

COMMANDER
NAVOCEANCOM
ATTN: J.W. OWNBEY, N542
NSTL STATION
BAY ST. LOUIS, MS 39529

COMMANDING OFFICER
NAVOCEANO, LIBRARY
NSTL STATION
BAY ST. LOUIS, MS 39522

COMMANDING OFFICER
FLENUMOCEANCEN
MONTEREY, CA 93940

COMMANDING OFFICER
NAVWESTOCEANCEN
BOX 113
PEARL HARBOR, HI 96860

COMMANDING OFFICER
NAVEASTOCEANCEN
MCADIE BLDG. (U-117)
NAVAL AIR STATION
NORFOLK, VA 23511

COMMANDING OFFICER
U.S. NAVOCEANCOMCEN
BOX 12 COMNAVMARIANAS
FPO SAN FRANCISCO 96630

COMMANDING OFFICER
U.S. NAVOCEANCOMCEN
BOX 31
FPO NEW YORK 09540

COMMANDING OFFICER
OCEANCOMFAC
P.O. BOX 85
NAVAL AIR STATION
JACKSONVILLE, FL 32212

SUPERINTENDENT
LIBRARY REPORTS
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

PRESIDENT
NAVAL WAR COLLEGE
ATTN: LCDR M. E. GIBBS
NEWPORT, RI 02840

CHAIRMAN
OCEANOGRAPHY DEPT.
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

COMMANDER
NAVAL SAFETY CENTER
NAVAL AIR STATION
NORFOLK, VA 23511

COMMANDER
NAVAIRSYSCOM
ATTN: LIBRARY, AIR-0004
WASHINGTON, DC 20361

COMMANDER
NAVAIRSYSCOM, AIR-370
WASHINGTON, DC 20361

COMMANDER
NAVAIRSYSCOM
MET. SYS. DIV., AIR-553
WASHINGTON, DC 20360

COMMANDER
EARTH & PLANETARY SCIENCES,
CODE 3918
NAVAL WEAPONS CENTER
CHINA LAKE, CA 93555

COMMANDER
PACMISTESTCEN, CODE 3250
ATTN: GEOPHYSICS OFFICER
PT. MUGU, CA 93042

CHIEF OF NAVAL EDUCATION &
TRAINING
NAVAL AIR STATION
PENSACOLA, FL 32508

CHIEF OF NAVAL AIR TRAINING
NAVAL AIR STATION
CORPUS CHRISTI, TX 78419

NAVAL POSTGRADUATE SCHOOL
DEPT. OF METEOROLOGY
MONTEREY, CA 93940

NAVAL POSTGRADUATE SCHOOL
DEPT. OF OCEANOGRAPHY
MONTEREY, CA 93940

NAVAL POSTGRADUATE SCHOOL
LIBRARY
MONTEREY, CA 93940

WEATHER SERVICE OFFICER
OPEATIONS CODE 16
MARINE CORPS AIR STATION
BEAUFORT, SC 29902

COMMANDING GENERAL
MARINE CORPS AIR STATION
ATTN: WEATHER OFFICE
CHERRY POINT, NC 28533

WEATHER SERVICE OFFICER
MARINE CORPS AIR FACILITY
QUANTICO, VA 22134

COMMANDING OFFICER
MARINE CORPS AIR STATION
ATTN: WEATHER SERVICE DIV.
HQHQRON OPERATIONS DEPT.
JACKSONVILLE, NC 28545

COMMANDER
AWS/DN
SCOTT AFB, IL 62225

USAFETAC/TS
SCOTT AFB, IL 62225

3350TH TECH. TRAINING GROUP
TTGU-W/STOP 623
CHANUTE AFB, IL 61868

AFGWC/DAPL
OFFUTT AFB, NE 68113

3 WW/DN
OFFUTT AFB, NE 68113

AFGL/LY
HANSCOM AFB, MA 01731

5WW/DN
LANGLEY AFB, VA 23665

OFFICER IN CHARGE
SERVICE SCHOOL COMMAND, GREAT LAKES
DET. CHANUTE/STOP 62
CHANUTE AFB, IL 61868

1ST WEATHER WING (DON)
HICKAM AFB, HI 96853

AFOSR/NC
BOLLING AFB
WASHINGTON, DC 20312

COMMANDING OFFICER
U.S. ARMY RESEARCH OFFICE
ATTN: GEOPHYSICS DIV.
P.O. BOX 12211
RESEARCH TRIANGLE PARK, NC 27709

DIRECTOR
ATTN: LIBRARY BRANCH
TECH. INFORMATION CENTER
U.S. ARMY ENGINEERS WATERWAYS EXPERIMENT STATION
VICKSBURG, MS 39180

DIRECTOR
DEFENSE TECH. INFORMATION CENTER, CAMERON STATION
ALEXANDRIA, VA 22314

DIRECTOR
OFFICE OF ENV. & LIFE SCI.
OFFICE OF THE UNDERSEC. OF DEFENSE FOR RSCH & ENG.
(E&LS) RM 3D129
THE PENTAGON
WASHINGTON, DC 20301

RDJFF-WLD
ATTN: LCDR THOMAS
RM. 1B-737, THE PENTAGON
WASHINGTON, DC 20301

COMMANDANT
U.S. COAST GUARD
WASHINGTON, DC 20226

CHIEF, MARINE SCIENCE SECTION
U.S. COAST GUARD ACADEMY
NEW LONDON, CT 06320

COMMANDING OFFICER
USCG RESTRACEN
YORKTOWN, VA 23690

COMMANDING OFFICER
U.S. COAST GUARD OCEANO UNIT
WASHINGTON NAVY YARD
BLDG. 159-E
WASHINGTON, DC 20390

COMMANDING OFFICER
USCG RESEARCH & DEV. CENTER
GROTON, CT 06340

DIRECTOR, SYSTEMS DEVELOPMENT
NWS/NOAA
RM 1216 - THE GRAMAX BLDG.
8060 13TH STREET
SILVER SPRING, MD 20910

DEVELOPMENT DIVISION
NATIONAL METEOROLOGICAL CENTER
NWS/NOAA, RM 204
WORLD WEATHER BLDG. W32
WASHINGTON, DC 20233

ACQUISITIONS SECT. IRDB-D823
LIBRARY & INFO. SERV. DIV. NOAA
6009 EXECUTIVE BLVD.
ROCKVILLE, MD 20852

CHIEF, MARINE & EARTH SCIENCES LIBRARY
NOAA, DEPT. OF COMMERCE
ROCKVILLE, MD 20852

NATIONAL OCEANIC & ATMOS. ADMIN.
OCEANOGRAPHIC SERVICES DIV.
6010 EXECUTIVE BLVD.
ROCKVILLE, MD 20852

DIRECTOR
OFFICE OF PROGRAMS RX3
NOAA RESEARCH LAB
BOULDER, CO 80302

DIRECTOR
NATIONAL HURRICANE CENTER, NOAA
UNIV. OF MIAMI BRANCH
CORAL GABLES, FL 33124

NATIONAL WEATHER SERVICE
WORLD WEATHER BLDG., RM 307
5200 AUTH ROAD
CAMP SPRINGS, MD 20023

NATIONAL CLIMATIC CENTER
ATTN: L. PRESTON D542X2
FEDERAL BLDG. - LIBRARY
ASHEVILLE, NC 28801

DIRECTOR
NATIONAL OCEANO. DATA, NOAA
DEPT. OF COMMERCE
ROCKVILLE, MD 20852

NATIONAL WEATHER SERVICE, EASTERN REGION: WFE3
585 STEWART AVE.
GARDEN CITY, NY 11530

CHIEF, SCIENTIFIC SERVICES
NWS/NOAA, SOUTHERN REGION
RM 10E09
819 TAYLOR STREET
FT. WORTH, TX 76102

NOAA RESEARCH FACILITIES CENTER
P.O. BOX 520197
MIAMI, FL 33152

METEOROLOGIST IN CAHRGE
NWS FORECAST OFFICE
TECHNOLOGY II, NOAA
NEW YORK UNIVERSITY
BRONX, NY 10453

DIRECTOR
ATLANTIC OCEANO & METEOR. LABS.
15 RICKENBACKER CAUSEWAY
VIRGINIA KEY
MIAMI, FL 33149

DIRECTOR, ATLANTIC MARINE CENTER
COAST & GEODETIC SURVEY, NOAA
439 WEST YORK STREET
NORFOLK, VA 23510

DIRECTOR
AOML NAT. HURRICANE RSCH. LAB.
1320 S. DIXIE HIGHWAY
CORAL GABLES, FL 33146

DIRECTOR, INTERNATIONAL AFFAIRS OFICE, NOAA
ATTN: MR. N. JOHNSON
6010 EXECUTIVE BLVD.
ROCKVILLE, MD 20852

DIRECTOR, DIV. OF ATMOS. SCI.
NATIONAL SCIENCE FOUNDATION
RM 644
1800 G STREET, NW
WASHINGTON, DC 20550

NASA GODDARD SPACE FLIGHT CENTER
ATMOSPHERIC SCIENCES LAB
GREENBELT, MD 20771

NASA GODDARD SPACE FLIGHT CENTER
PRELIMINARY SYSTEMD DESIGN GROUP
GREENBELT, MD 20771

EXECUTIVE SECRETARY
CAO SUBCOMMITTEE ON ATMOS. SCI.
NATIONAL SCIENCE FOUNDATION,
ROOM 510
1800 G. STREET, NW
WASHINGTON, DC 20550

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)
1725 I STREET, NW
WASHINGTON, DC 20472

COLORADO STATE UNIVERSITY
DEPT. OF ATMOS. SCIENCES
ATTN: LIBRARIAN
FORT COLLINS, CO 80521

CHAIRMAN
MASSACHUSETTS INSTITUTE OF TECH.
DEPT. OF METEOROLOGY
CAMBRIDGE, MA 02139

UNIVERSITY OF WASHINGTON
ATMOSPHERIC SCIENCES DEPT.
SEATTLE, WA 98195

FLORIDA STATE UNIVERSITY
ENVIRONMENTAL SCIENCES DEPT.
TALLAHASSEE, FL 32306

UNIVERSITY OF HAWAII
DEPT. OF METEOROLOGY
2525 CORREA ROAD
HONOLULU, HI 96822

TEXAS A&M UNIVERSITY
DEPT. OF METEOROLOGY
COLLEGE STATION, TX 77843

DIRECTOR OF RESEARCH
UNIVERSITY OF ST. THOMAS
INSTITUTE FOR STORM RESEARCH
3812 MONTROSE BLVD.
HOUSTON, TX 77006

CHAIRMAN
UNIVERSITY OF FLORIDA
DEPT. OF METEOROLOGY & PHYSICS
215 PHYSICS BLDG.
GAINESVILLE, FL 32601

DOCUMENTS/REPORTS SECTION
LIBRARY
SCRIPPS INSTITUTION OF OCEANO.
LA JOLLA, CA 92037

DIRECTOR
OCEANOGRAPHIC INSTITUTE
OLD DOMINION UNIVERSITY
NORFOLK, VA 23508

UNIVERSITY OF MIAMI
R.S.M.A.S. LIBRARY
4600 RICKENBACKER CAUSEWAY
VIRGINIA KEY
MIAMI, FL 33149

CHAIRMAN
DEPT. OF ATMOSPHERIC SCIENCES
UNIV. OF VIRGINIA, CLARK HALL
CHARLOTTESVILLE, VA 22903

ATMOSPHERIC SCIENCES DEPT.
UCLA
405 HILGARD AVE.
LOS ANGELES, CA 90024

COLORADO STATE UNIVERSITY
DEPT. OF ATMOSPHERIC SCIENCES
LIBRARY, FOOTHILLS CAMPUS
FT. COLLINS, CO 80523

UNIVERSITY OF MARYLAND
DEPT. OF METEOROLOGY
COLLEGE PARK, MD 20742

THE EXECUTIVE DIRECTOR
AMERICAN METEOR. SOCIETY
45 BEACON STREET
BOSTON, MA 02108

AMERICAN METEOR. SOCIETY
MET. & GEOASTRO. ABSTRACTS
PO BOX 1736
WASHINGTON, DC 20013

DIRECTOR, JTWC
BOX 17
FPO SAN FRANCISCO 96630

WORLD METEOROLOGICAL ORG.
ATS DIVISION
ATTN: N. SUZUKI
CH-1211, GENEVA 20,
SWITZERLAND

BUREAU OF METEOROLOGY
ATTN: LIBRARY
BOX 1289K, GPO
MELBOURNE, VIC, 3001
AUSTRALIA

DIRECTOR OF NAVAL OCEANOGRAPHY
& METEOROLOGY
MINISTRY OF DEFENCE
OLD WAR OFFICE BLDG.
LONDON, S.W.1. ENGLAND

METEOROLOGICAL OFFICE LIBRARY
LONDON ROAD
BRACKNELL, BERKSHIRE
RG 12 2SZ
ENGLAND

MINISTRY OF DEFENCE
NAVY DEPARTMENT
ADMIRALTY RESEARCH LAB
TEDDINGTON, MIDDX
ENGLAND

TYPHOON RESEARCH LABORATORY
ATTN: LIBRARIAN
METEOROLOGICAL RESEARCH
INSTITUTE
1-1 NAGAMINE, YATABE-MACHI,
TSUKUBA-GUN
IBARAKI-KEN, 305, JAPAN

DIRECCION GENERAL DE OCEANO-
GRAFIA SENALAMIENTO MARITIMO
MEDELLIN NO. 10
MEXICO, 7, D.F.

NATIONAL TAIWAN UNIVERSITY
DEPT. OF ATMOSPHERIC SCIENCE
TAIPEI, TAIWAN 107

DATE

ILMED

8